BULK METALLIC GLASS COMPOSITES: MICROSTRUCTURAL INFLUENCES ON MECHANICAL PROPERTIES

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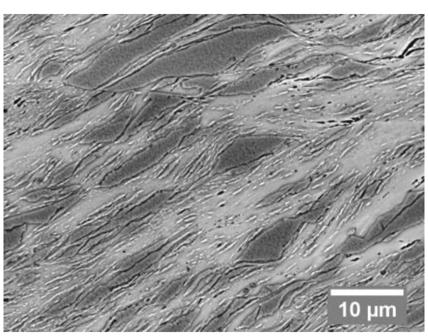
Bulk metallic glasses (BMGs) have been strongly investigated as they show on the one hand interesting mechanical properties as high strength and good wear resistance but on the other hand limited ductile deformability. Bulk metallic glass composites (BMGCs) are very promising to overcome and improve the properties by clever combination of different phases. However, a major drawback is the limited choices of phase combinations in common fabrication routes and lack of major microstructure adjustability. A promising technique to overcome these drawbacks is severe plastic deformation process, e.g. high pressure torsion (HPT), where the production can be started with metallic glass powders. For this route, the powder is consolidated and deformed by applying a high shear deformation to bulk samples. Therefore, it is possible to produce fully amorphous specimens [1], but also composites containing two different amorphous phases or an amorphous and a crystalline one [2].

This work concentrates on two main points: Firstly, the structural evolution of the composites was characterized. The influence of the applied deformation for the different composites (varying the two phases and also the ratio of them) was investigated. For this SEM, TEM and XRD were used. Secondly, the influences on the mechanical properties of the composites were investigated. Micromechanical testing methods such as nanoindentation, in-situ SEM micropillar compression, and finally in situ TEM picoindentation were carried out to investigate the deformation behavior under ambient but also non-ambient conditions. Using nanoindentation, the hardness and the Young's Modulus was determined and additional high temperature nanoindentation experiments up to 400 °C showed that shear band formation depends on temperature and composition. Overcoming 300 °C, the material becomes extremely ductile showing a strong strain rate sensitivity.

Further, the uniaxial mechanical response of single-phased BMGs and BMGCs was examined in-situ in SEM using FIB prepared micropillars. The microcompression experiments revealed that the strength varies between 1.7 and 2.7 GPa depending on the combination of the phases, the lamellae size and also on the lamellae orientation. Steps in the stress-strain curve suggest shear band formation, which could also be confirmed by the in-situ recorded SEM images and different deformation behavior can be found for the different specimens.

[1] Krämer, L.; Kormout, K.S.; Setman, D.; Champion, Y.; Pippan, R. Production of Bulk Metallic Glasses by Severe Plastic Deformation. Metals 2015, 5, 720-729.
[2] Krämer, L., Champion, Y. & Pippan, R. From powders to bulk metallic glass composites. Scientific Reports 2017, 7, 6651.



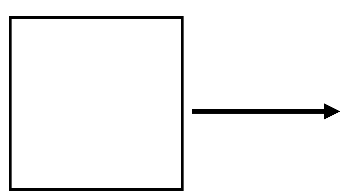


Figure 1 – SEM micrographs of two BMGCs. On the left side an amorphous/amorphous composite and in the middle an amorphous/crystalline composite can be seen. A tested micro pillar (amorphous/crystalline) is shown on the right side.